Simon Fraser University
Burnaby BC
V5A 1S6
jmy@sfu.ca

To: Steve Whitmore
Communication Lecturer
Simon Fraser University
Burnaby BC
V5A 1S6

Dear Mr. Whitmore,

Hello and thank you for your interest in the technologies and processes used at LightTouch Limited. The enclosed document, LightTouch Limited Functional Specification, details the basic, high level functional blocks of our prototype PC pointing device. We review specific component restrictions, functionality requirements, and design intentions in this document. For more information, please review our enclosed Executive Summary.

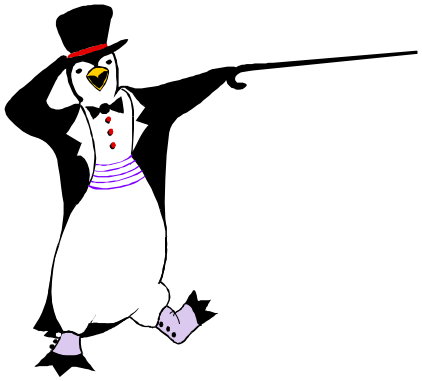
Our functional proposal will allow you to examine the functional components of our next generation PC pointing device. If you have any questions or concerns, please feel free to contact me at jmy@sfu.ca.

Yours Truly,

Jonathan Young
VP Customer Support
LightTouch Limited

LightTouch System

Functional Specification



LightTouch Limited
Simon Fraser University
Burnaby BC
V5A 1S6
jmy@sfu.ca

March 5, 1999

Steve Whitmore
Simon Fraser University
8888 University Drive
Burnaby BC

Executive Summary

LightTouch Limited's functional specification outlines the basic functional blocks which, working together, will provide the basis of a new, intuitive hand-to-screen pointing device. Our main functional blocks are: Optical sensor, Digital signal processing, PC interface hardware, and PC driver software.

The optical sensor section consists of low cost, reliable and proven sensor components, as has been proven in the engineering industry over several years. Our digital signal processing component will be fast and reliable, comprising of original work by our company in order to produce the most efficient, reliable and cost effective processing of sensor data. The PC interface will consist of a standard parallel port, which is a standard fixture found on virtually every popular computer type today, including the Windows PC, Apple Macintosh, and most UNIX workstations. Our PC driver software will demonstrate the viability of our idea by communicating to a computer operating system pointer movements in a user interface.

We conclude our report by outlining a test plan by which we will indicate what tests we will perform, which must be successfully completed in order for our product to be successful. You can expect to successfully be able to perform all tests outlined in our test plan with our completed prototype.

Please feel free to browse through the contents of our functional specification for a broad overview of our work. For more detailed documentation of our solution, please refer to our forthcoming design document.

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1. Introduction

With the blossoming of the personal computer as a standard accompaniment to modern homes and offices has come the desire to control these tools with greater ease and efficiency. Graphical user interfaces allow us to communicate our desires to our computers quickly and intuitively. The recent development of computer touch screens provides computer users a more interactive and intuitive way to interface with computers. However the computer touch screen available on the market is not practical to the large-scale display device, such as a projection screen, because of its size and cost. The LightTouch touch screen system is designed to overcome these two disadvantages of the traditional touch screen. In addition, the LightTouch touch screen system is more portable and flexible such that it can be easily attached to different display devices of different sizes.

The purpose of this document is to describe the functional requirements of LightTouch system and the deliverables of LightTouch Limited to its customers. The audience for this work is Dr. Andrew Rawics, Mr. Steve Whitmore, the design engineers of LightTouch Limited, and external design consultants.

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2. Background

The LightTouch touch screen system recognizes the location of the physical pointing object on the display by detecting the intensity change in the visible light pattern. Notice the hand touching the surface of the display screen as illustrated in Figure 2.1 below. The intensity pattern is processed and translated into the x-y coordinates of the physical pointer. Visible light is chosen as the input signal source of the LightTouch for two main reasons. No special or complex input sources are required, and there are a variety of high quality and low-cost visible light sensors available on the market.

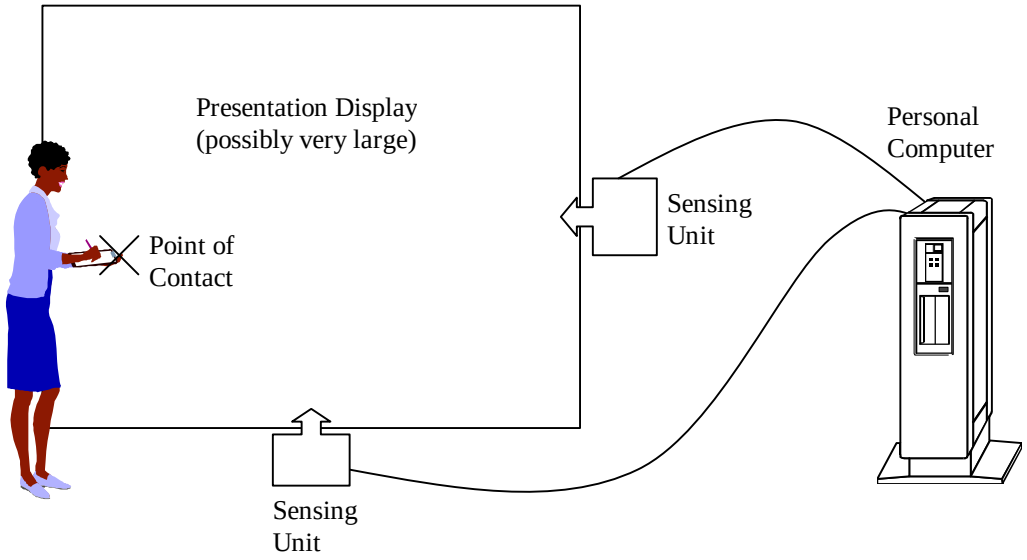

Figure 2.1. System Background Overview

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3. System Overview

The LightTouch system will obtain input in the form of a light intensity pattern, that reflects the user movement on the display device. The system will then generate an output to either reposition the pointer, or execute pointer button action on the graphical user interface. Figure 3.1 below shows the system input/output diagram.

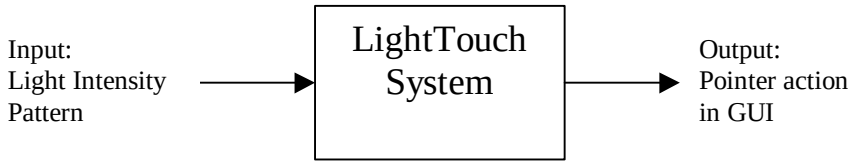

Figure 3.1. System Input/Output Diagram

Figure 3.2 shows the LightTouch system block diagram. The functionality of each block is explained in more detail in later sections.

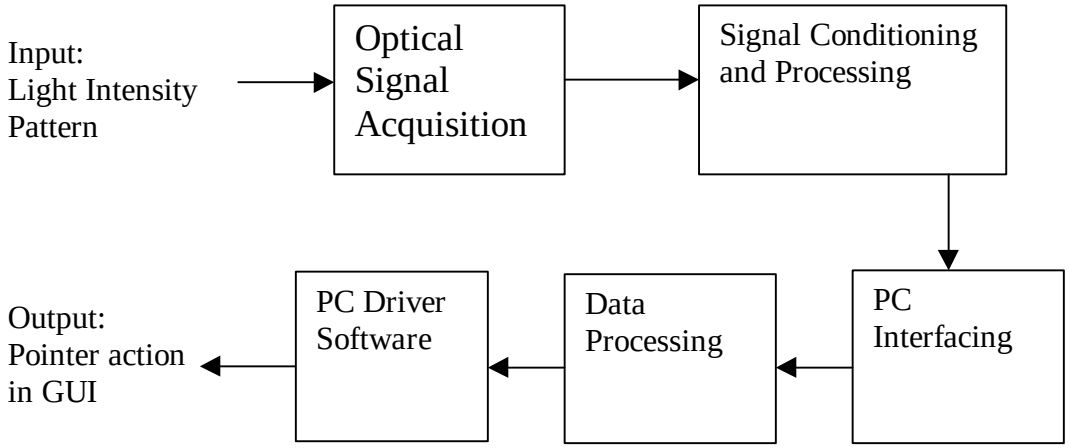

Figure 3.2. System Block Diagram

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The functional blocks shown in Figure 2 will combine to satisfy the following system functional requirements.

The LightTouch system will

- use visible light sensors to capture the light intensity pattern that reflects the presence of a physical object in the two dimensional space.
- recognize the light intensity pattern and translate it to the x-y coordinates on the graphical user interface.
- Use x-y coordinates to reposition the pointer or execute the pointer button action in an operating system compatible data format
- have a maximum response time of 0.5 seconds; response time is time between a user touching the display screen and the computer recognizing the x-y coordinate location.
- have two LEDs, one indicating that power is being supplied to the hardware sensing unit, and the other reflecting the signal processing status.
- utilize an external AC power adapter to provide DC power to the system.
- have an on/off switch.

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4. Optical Signal Acquisition

The first stage of the LightTouch system will acquire the light intensity pattern from the surface of the display screen. Figure 4.1 below shows the context diagram of this stage.

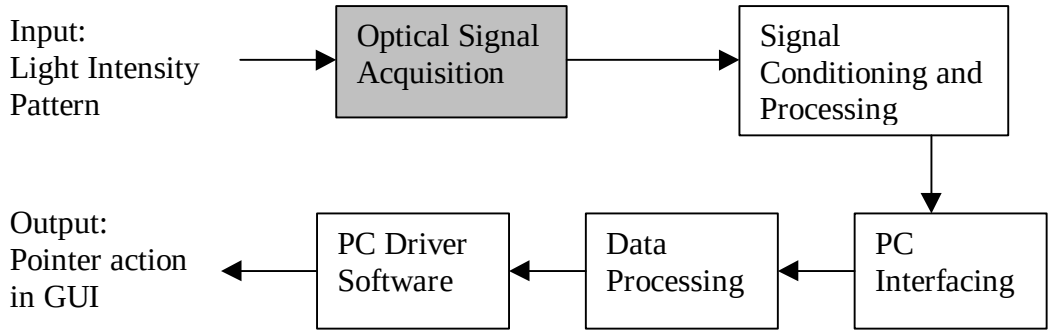

Figure 4.1. Optical Signal Acquisition Stage Context Diagram

Figure 4.2 below shows the functional block diagram of this stage.

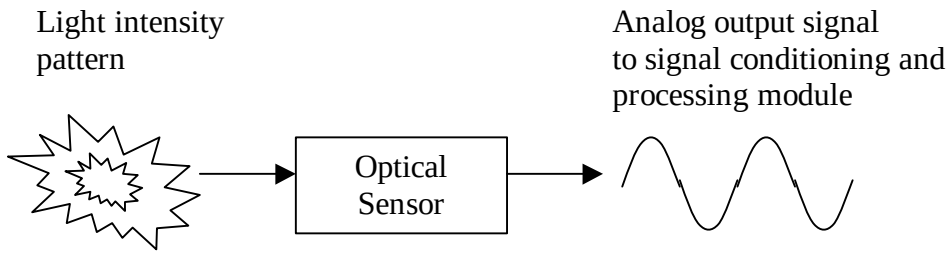

Figure 4.2. Optical Signal Acquisition Stage Functional Block Diagram

The specific type of optical sensor to be used will:

- have an input light bandwidth covering the range of visible light.
- have a minimum input bandwidth of 10Hz.
- cover a minimum 14 inch display area.
- have a minimum resolution of 160 X 120 pixels.
- have good noise-to-signal ratio.

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5. Signal Conditioning and Processing

The second stage of the LightTouch system will condition and modify the analog output signal from the optical signal acquisition module. Figure 5.1 below shows the context diagram of this stage.

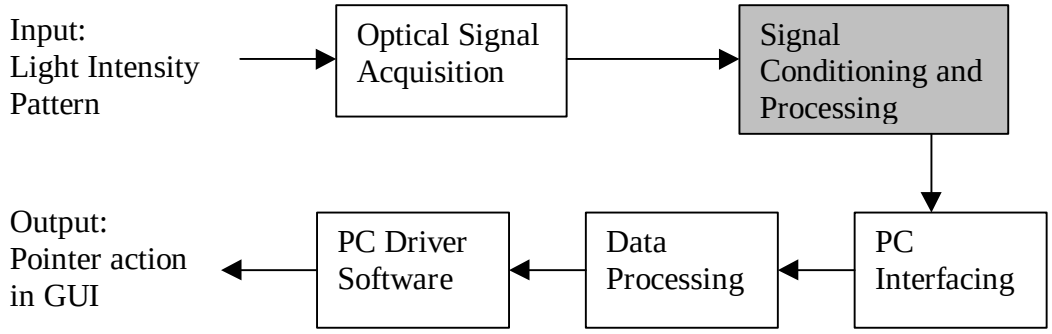

Figure 5.1. Signal Conditioning and Processing Stage Context Diagram

Figure 5.2 below shows the functional block diagram of this stage.

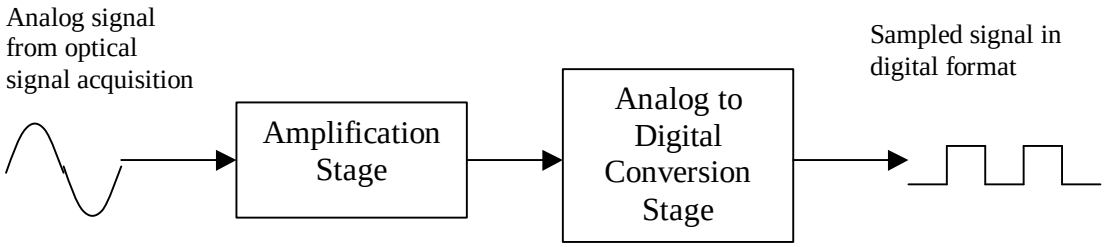

Figure 5.2. Signal Conditioning and Processing Stage Functional Block Diagram

The signal conditioning and processing block of the LightTouch system will

- have an amplifier that can amplify the acquired analog optical signal to the level required by the analog-to-digital converter.
- have an analog-to-digital converter that has a sampling frequency at least two times the frequency of the acquired analog optical signal.
- have an analog-to-digital converter with a minimum 8 bit resolution.

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6. PC Interfacing

The third stage of the LightTouch system will receive the sampled digital signal from the signal conditioning and processing module. Digital data will then be transmitted to the host PC in an operating system compatible data format, at approximately maximum parallel port speed. Figure 6.1 below shows the context diagram of this stage.

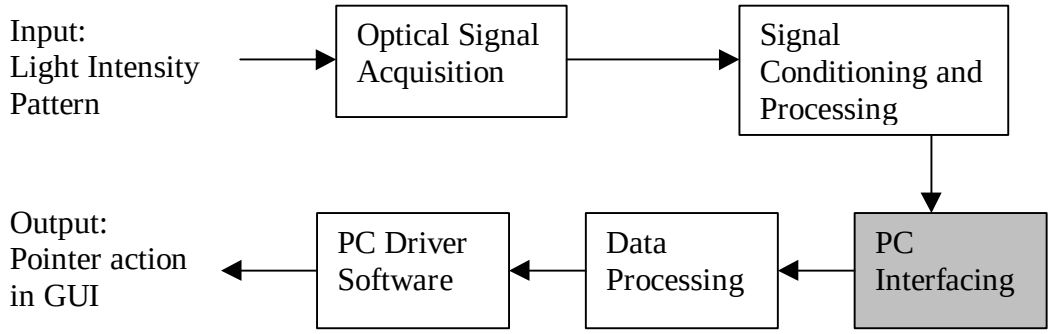

Figure 6.1. PC Interfacing Stage Context Diagram

Figure 6.2 below shows the functional block diagram of this stage.

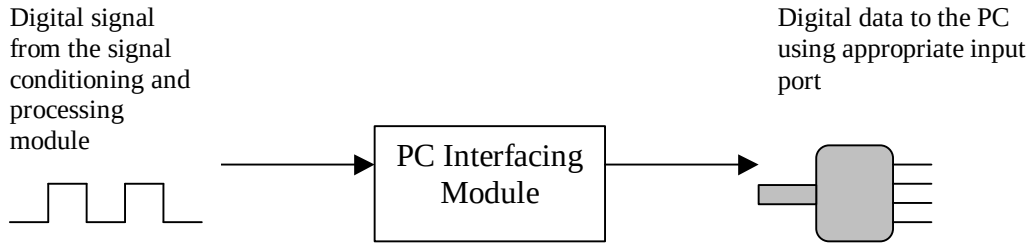

Figure 6.2. PC Interfacing Stage Functional Block Diagram

The PC interfacing block of the LightTouch system will

- convert the digital signal into digital data and transmit it to the PC in a format compatible to the PC input port.
- send the sampled data at the rate of at least 22.4Kbits/sec so that sufficient data can be received by the PC for data processing.

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7. Data Processing

The fourth stage of the LightTouch system will receive the sampled digital signal from the signal conditioning and processing module. Digital data will then be transmitted to the host PC using appropriate format and protocol. Figure 7.1 below shows the context diagram of this stage.

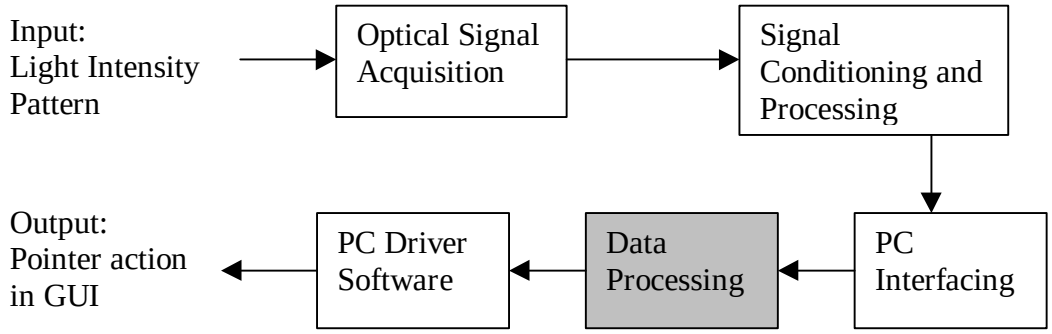

Figure 7.1. Data Processing Stage Context Diagram

Figure 7.2 below shows the functional block diagram of this stage.

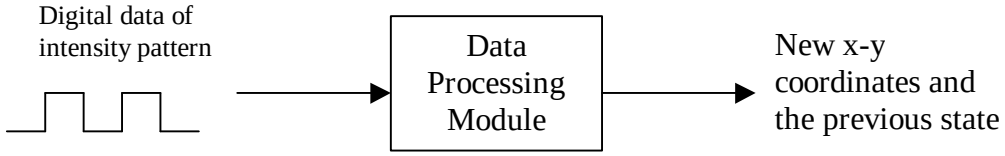

Figure 7.2. Data Processing Stage Functional Block Diagram

The data processing module of the LightTouch system will

- receive the raw digital image data, and extract the x-y coordinates of the pointing object of the display screen, in digital format.
- determine the x-y coordinates by analyzing the change in the binary pattern of raw image data.
- determine the presence of the pointing object.
- keep track of the previous location of the pointing object.
- generate no output if there is no change in the input.

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- output the data synchronously fast enough such that the processing does not fall behind the rate of the input.

8. PC Driver Software

The fifth stage of the LightTouch system will receive the new x-y coordinates and the previous button state from the data processing module. It will then take action to control the pointer on the graphical user interface, in the operating system. Figure 8.1 below shows the context diagram of this stage.

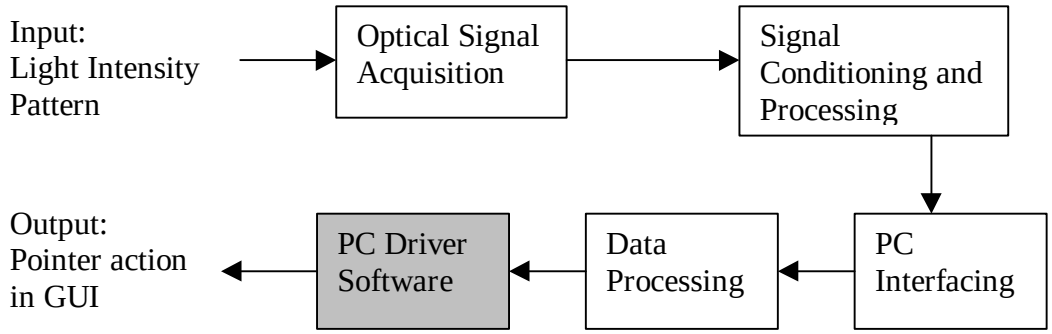

Figure 8.1. PC Driver Software Stage Context Diagram

Figure 8.2 below shows the functional block diagram of this stage.

Figure 8.2. PC Driver Software Stage Functional Block Diagram

The PC driver software module of the LightTouch system will

- inform the operating system to adjust the position of the pointer or execute button action.
- perform no action if there is no change in x-y coordinates.
- perform no action if the x-y coordinates are invalid.

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9. Requirements and Limitations

Physical Requirements

The size of sensor units of the LightTouch system will be portable so that they can be mounted on different display screens with minimum difficulty. Unit size and appearance will also pose minimal distraction from the contents of the display screen.

Accuracy Requirements

The minimum response accuracy of the LightTouch system will be 90%, meaning nine out of ten times the system recognizes and interprets the user action correctly.

Durability Requirements

The LightTouch system will be able to operate continuously for a minimum of three years.

Potential System Limitations

The LightTouch system may be limited by the following factors:

- The size of the pointing object has to be large enough to be detected by the optical sensor.
- Only a single-point screen contact is allowed.
- The background image has to be reasonably stable for our image detection algorithm to work
- The blank state background image needs to be periodically updated by either manual or automatic activation of a system is set up procedure.
- The ambient light should not change significantly.

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10. Test Plan

The LightTouch system will be tested in the following areas:

Pointer Accuracy

We will test pointer accuracy in the following nine section of the screen, shown in Figure 10.1:

A1	B2	C2
A2	B2	C2
A3	B3	C3

For each section, we will test pointer accuracy by pointing to a random point in each section, and measuring the distance of error between our physical pointer location and the computer interpreted pointer location. Distance of error in each case should be less than 20 pixels or 3cm, whichever is larger.

Minimum Pointer Size

We will test for LightTouch system recognition of pointers of roughly circular shape. Using our finger as a pointer will be tested, as well as a standard pencil and a human fist. We should be able to pick up a pointer of human fingertip size.

Button Click Time Delay

We will use a software timer on our PC to ensure that the maximum time delay between separately recognizable button clicks is 1 second.

Pointer Movement Tracking

The LightTouch system should be able to follow a moving pointer on the computer display in a continuous, button down state if the pointer moves at a maximum of 5 cm per second.

If our product passes all these tests, we will consider our functional requirements fulfilled.

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11. Conclusion

This document discusses the functional requirements and considerations of building an optical sensor based touch screen system. Data will flow from the optical sensor, where it will be converted from analog to digital information. The digital picture will then be transmitted over a parallel port connection to the PC, where it will be run through an image processing algorithm. Once a x-y computer display coordinate can be determined, it will be passed on the operating system driver code, which will activate mouse-like actions.

The LightTouch system will be built according to the functional specifications described here. By following these consideration guidelines, it is believed that the LightTouch system will potentially be a better touch screen system, especially for the large scale display devices. Our functional specification describes the block functionality of a more intuitive and more interactive computer user interface.

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